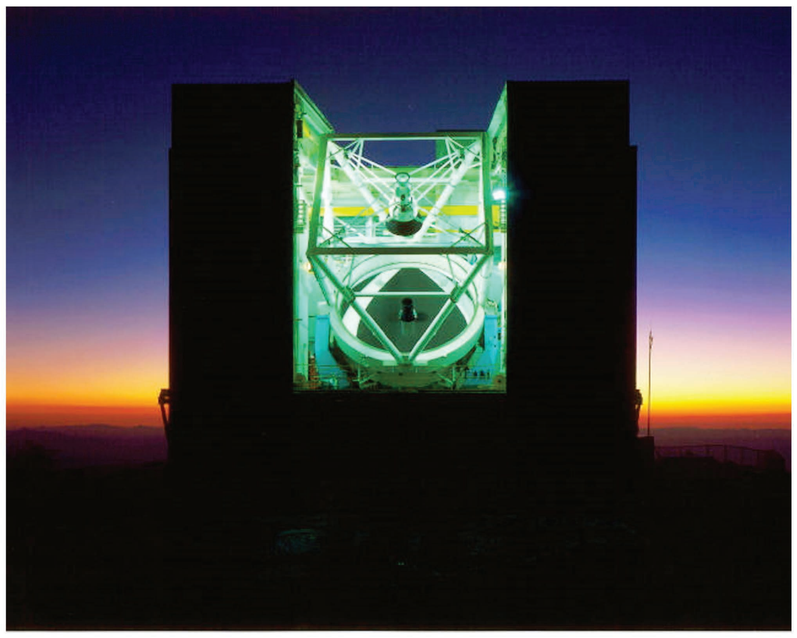
On-Orbit Aging of SL-12 Rocket Bodies

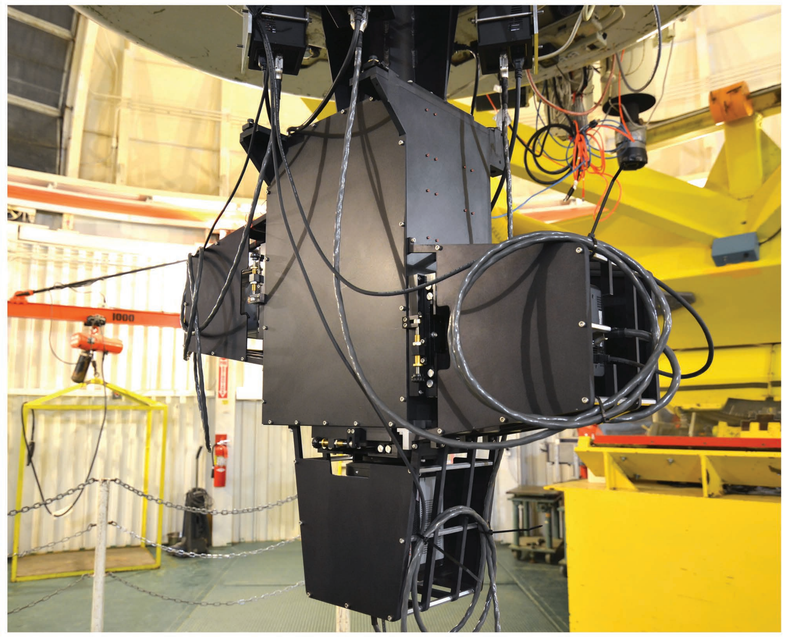
Eric C. Pearce*, Benjamin Weiner†, Harrison Krantz*, Kris Rockowitz*

*Steward Observatory, University of Arizona †MMT Observatory



MMT Observatory, Arizona 6.5m aperture

MMT During the Day



Chimera 3-channel high speed photometer, Kuiper Telescope 1.54m aperture

Abstract

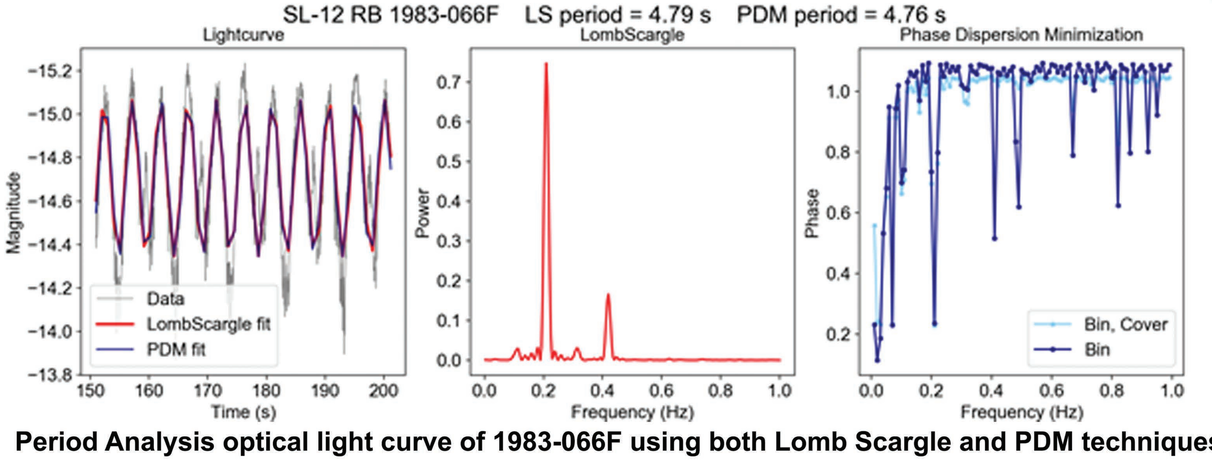
The characterization of deep space debris has posed a significant challenge in SSA. To be most operationally effective, characterization must be performed quickly and under non-ideal operational conditions, generally using non-resolved techniques. The use of multi-color photometry and the resultant color indices offer the potential to rapidly discriminate between debris and intact space objects such as rocket bodies and satellites. However, these studies are not well informed by high resolution spectra of these same objects due to the lack of prior measurements with large astronomical telescopes. High resolution spectroscopy is not routinely collected by our SSA network. Nonetheless, several researchers have collected satellite spectra for research purposes and noted the progressive reddening of spacecraft surfaces with age.

In this study, we re-analyze our previous UKIRT near-IR five-color photometric measurements of SL-12 fourth stage rocket bodies with the additional context of high-resolution visible band spectra on the same objects. The SL-12 fourth stage rocket bodies (henceforth referred to as "SL-12 RB") offer a convenient ensemble of objects for which photometric techniques can be developed and tested. The SL-12 (also called the "Proton K") was a mainstay Russian four-stage to GEO launch vehicle that was used from 1974 to 2012. The five SL-12s measured have a range of years-on-orbit (YOO) from 23-35 years, allowing a comparative study of the evolution of the spectra over a 12-year difference in age. The spectra were collected with the Blue Channel Spectrograph on the 6.5 m MMT telescope at Mt. Hopkins. The spectra cover a 5200 Å range at a dispersion of 1.96 Å/pixel. The large collecting aperture of the MMT allowed the rapid collection of multiple high signal-to-noise spectra with short 2-minute exposures. This short exposure allows us to have confidence the solar phase angle was near constant during each collection, but that the spectra were averaged over the rotation of the rocket body. In addition to the UKIRT measurements, we supplement the analysis data with Sloan r', i', and z' high speed photometric data with the Chimera High-Speed photometer on the Kuiper 61" telescope at Mt. Bigelow near Tucson AZ. The spectra are analyzed for evidence of the effects of on-orbit ageing.

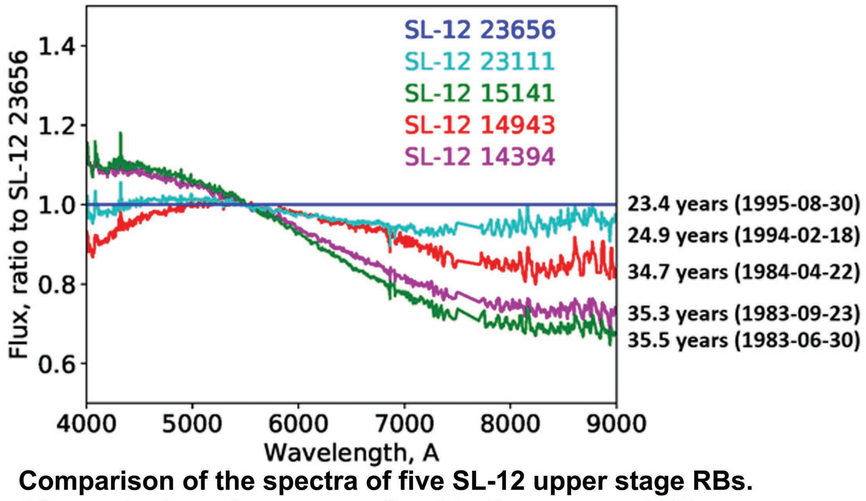
Chimera Specifications

Chimera is a three-color high-speed EMCCD-based photometer for space surveillance and astronomy. The utilization of color-indices, instead of absolute photometry, greatly simplifies calibration and allows the technique to be used under a broad range of operational conditions. The Chimera instrument is optimized for use on the Steward Observatory 1.54m Kuiper Telescope located on Mt. Bigelow, and is routinely used by various SSA and astronomical observing programs.

Band	Resolution	FOV (arcmin)	Full Frame with Binning (fps)			ROI (32x32) with Binning (fps)		
			1x1	2x2	4x4	1x1	2x2	4x4
r'	512x512	6.0	61	120	228	711	1099	1506
i'	512x512	6.0	61	120	228	711	1099	1506
z'	1024x1024	9.7	25	48	89	481	675	847



Period Analysis optical light curve of 1983-066F using both Lomb Scargle and PDM techniques.

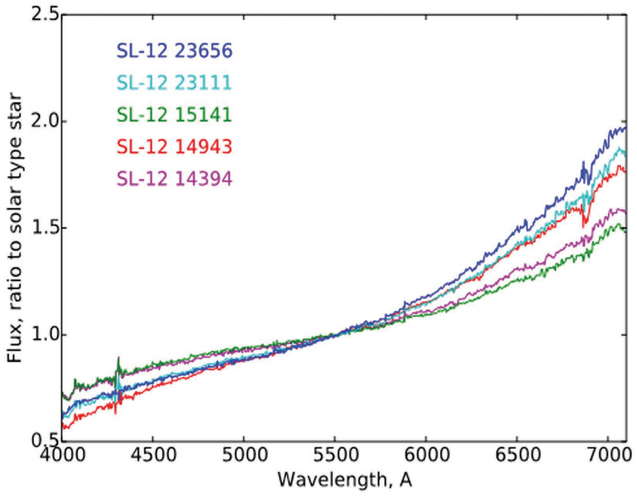


Comparison of the spectra of five SL-12 upper stage RBs. All spectra have been normalized to the youngest RB, 1995-045D (23656).

Unexpected Results

Our MMT visible band spectra represent a unique data set in the community, measuring similar objects over an 18-year span of years-on-orbit and showing systematic bluing with age. Contrary to expectations, the systematic bluing of the spectra appears to continue monotonically even after 35 years on orbit. In the future, using Chimera, we plan to create a similar data set to the MMT SL-12 RB spectra here that can be used to systematically study the effects of aging in those spectral bands and inform our interpretation of the near-IR color indices in that context.

Our spectral measurements with MMT show for the first time compelling evidence for spectral evolution and demonstrate that for this class of object, this effect results in a systematic decrease in reflectiveness in the red. Over the next year we will refine our techniques and develop methods for rapid object characterization while looking towards high resolution observations such as spectrometry.



See the Crab Nebula Pulsar Flashing Video

Scan me

Dr. Eric C Pearce
Professor, Astronomy
College of Science

THE UNIVERSITY OF ARIZONA
Steward Observatory
Room N514
933 N Cherry Ave
Tucson AZ 85719

epearce@email.arizona.edu
www.as.arizona.edu

Office: 520-612-2309
Cell: 520-352-9327